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EXPLANATORY NOTES TO THE ARTICLE BY DR.
LUNDMARK IN NUMBER 200 OF THIS JOURNAL

By J. G. HAGEN, S. J.

Dr. Lundmark has made a very careful study of various papers that have so far appeared on visual cosmic clouds. The few objections he raises serve as a welcome opportunity for additional explanations.

Preceding the papers of his list there are three others: Via Lattea e Via Nubila, *Memorie della Societa Astron. Italiana* 1 (1920) 1;

Jahresbericht der Vatican-Sternwarte für 1919, *V. J. S. der A. G.* 55 (1920) 3. Heft. (See our *Miscellanea Astron.* I [1920] 41);

Jahresbericht der Vatikan-Sternwarte für 1921, *ibid.* 57 (1922) 2. Heft.

The last paper may have appeared after Dr. Lundmark's article was written. Since then, two more treatises were issued and presented to the International Astronomical Union, which met at Rome in 1922:

A *DM* of the Heavens for Obscure Cosmic Clouds. The equatorial zone, Part I, *Atti della Pont. Accad. Romana dei Nuovi Lincei* 1922;

The Obscure Cosmic Clouds South of ζ *Orionis*, *ibid.*

All these papers are only preliminary announcements. The body of the observations is contained in our publications:

A Preparatory Catalogue for a *DM* of Nebulæ, first instalment, Zones 0° to 60° N. P. D., which was likewise presented to the Union and is now being distributed. Another volume is in preparation, entitled:

A *Durchmusterung* of Obscure Nebulæ.

To come to a full understanding, a clear distinction is to be made between Observations, Conclusions and Explanations.

The strongest part are the Observations, because they rest on numerical data which can be verified by everyone. Conclusions will always remain open to discussion, while the Explana-

tions, the weakest part of all, must naturally change in proportion as new discoveries are made.

I. THE OBSERVATIONS

The observations made at the Vatican Observatory during the last twelve years are of two kinds, those of the bright nebulae, contained in Dreyer's *N. G. C.*, with a description of the dark clouds around each nebula, and others by independent sweeping. These latter ones are correctly described by Dr. Lundmark.

1. The difficulty of seeing the clouds is not great, once the instrument is aptly chosen and the secret is understood. It is not only "the dullness of the field and the absence of stars" that reveals the dark nebulae; it is the sweeping with the telescope and often also regular chains of stars that line the borders of the clouds.

Whether "a larger focal ratio and a field of several degrees" is the best equipment remains to be seen. Too much light in the field of view may be a hindrance.

Our telescope shows the entire sky covered with obscure nebulae, densest at the galactic north pole. Within the Milky Way only separate patches of thin veils are seen, but a perfectly clear and dark looking sky is not found except around dense clusters of stars. Visually, therefore, the dark nebulae *are not a galactic phenomenon*.

2. Dr. Lundmark justly demands that these observations be repeated by another observer, in another climate. Indeed, four observatories have been invited and urged to join in our observations and, in particular, to review the galactic south pole. But the test can only be made visually. If Barnard's and Hubble's extensive photographic studies of dark nebulae "have given as one main result that these are Milky Way objects related to the star clouds," it is because dark nebulae cannot be photographed except near bright stars which illuminate them or excite them to luminosity. The writer even predicted that a plate exposed to the galactic pole will not show any picture.

"Long-exposure photographs made with color screens" will undoubtedly bring out contrasts that are inaccessible to the eye,

but only where the stars are very bright or very numerous. A good example is the famous notch south of ζ *Orionis*. That it "cannot be made out with any definiteness by visual observations" does *not* illustrate "the difficulties of observing dark nebulae visually"; it was rather to be expected, because the streak of light which passes behind the notch and which produces the contrast, is too faint even for the Yerkes refractor.

For making a systematic visual test of the writer's observations some guide will be necessary. Professor Barnard's catalogue of "Dark Markings" would not be the proper one for the purpose, as it contains only a few nebulae which he has *seen* and which are certainly dark clouds. The rest are probably not nebulae but rather "real vacancies among the stars," as Dr. Lundmark rightly observes. A conspicuous example of a "dark lane," visible to the unaided eye, is the bifurcation of the Milky Way, near *Cygnus* and *Aquila*. The space between the two branches seems to have a darker hue than the sky outside and is remarkably vacant of stars. Has any scientist ever thought of explaining that lane by an opaque nebula in front of it?

A better guide will be the "Preparatory Catalogue." One need only point the telescope to any object in Dreyer's *N. G. C.* and read the description of the surrounding dark nebulae which the writer gives in Table II (right-hand page) of that catalogue. Later on, when the observer has made himself familiar with the five grades of density, the "Durchmusterung" will form the severest test. Parts of it are published in the *Jubiläums Nr.* and in the *Atti* mentioned above.

3. The effects of the zodiacal light, of the so-called earth light and of color equation are mentioned by Dr. Lundmark as possible sources of error. More serious obstacles seem to be atmospheric extinction and the electric illumination of cities.

The appearance of the zodiacal light in the telescope is mentioned in the article published in the *Atti*. Recent observations have shown that this "light," as it is called, is so far from being a source of error, that it rather forms the best example of a dark nebula, being itself one of those interstellar nebulous streaks that are seen throughout the Milky Way, and by chance situ-

ated near our solar system. The reason for this assertion will be given elsewhere.

Thus, the difference between dark markings and dark nebulae is conspicuously illustrated in the heavens by the branches of the Milky Way and by the zodiacal light.

The color equation of the writer can be judged from the publication "Colori Stellari," *Spec. Vat.* Serie II, No. III. The reobservation of all of Sestini's stars does not seem to indicate an error of the kind. Besides, the dark clouds have a grayish, neutral tint, which can be distinguished from a clear sky even by one who is partly color blind.

So far no correction has been applied to the estimates of density for the absorption of light from the various sources. It seems better to make a cursory *DM* of the whole sky before any discussion of details is attempted.

II. THE CONCLUSIONS

The conclusions that were drawn from the observations are correctly stated by Dr. Lundmark, but may be supplemented in this way:

1. Not only the dark nebulae "surround the Milky Way system as a hollow shell" but the bright nebulae as well, because they are intimately associated with the clouds and are hardly ever seen without them. In fact, the denser the cloud, the more abundant the lucent nebulae; and more, the spirals as well as all the bright nebulae show a decided preference to line the shores of cloudy continents and to avoid the interior regions.

2. If "the hypothesis that the stars originate from the dark nebulae" holds, and if Russell's theory of stellar evolution is assumed, the connection between the two is obvious. Evidently the young giant stars presuppose the existence of extended matter of low temperature.

The first conclusion is based on the view that it seems to leave no alternative except this, that the universe is composed of three parallel walls or sheets of matter, two of dark clouds and between them the galaxy.

The second conclusion rests on the observation that the sky

is clearest around dense clusters and partly clear in the Milky Way.

III. THE EXPLANATIONS

The purpose of the explanations is to bring the conclusions into harmony with known facts and to remove apparent contradictions.

1. The main difficulty against the first conclusion is this: If dark and bright nebulae surround the galactic system, why are they not seen in the direction of the galactic equator? An obvious reason seemed to be their greater distance, since the equatorial diameter of the Milky Way may be assumed about six times greater than the polar diameter.

As regards the bright nebulae, Dr. Lundmark rightly observes that it is "the total amount of light" that would appear thirty-six times fainter, while the intrinsic luminosity of the nebula remains the same; only the diameter of a nebula would appear six times smaller. But even that seems to answer the question, at least for the average sized objects.

The average of the diameter, published in the Preparatory Catalogue, of the nebulae contained in Dreyer's Catalogue, seems to be about 0'.2. At six times the distance it would be 2". Star images of that size belong to the smallest ones well visible on the astrographic plates. Whether a nebula of the same size can be well seen, is another question; and whether it can be distinguished on a plate studded with thousands of stars, is still another question.

The brighter nebulae should, according to Dr. Lundmark, have an integrated magnitude of about 12, if they were six times as far away. Suppose the 569 bright nebulae, described in the *Lick Obs. Publ.* Vol. XIII (Pt. I, page 12), are all of the larger kind. Since they lie outside the Milky Way, or in two-thirds of the celestial sphere, there ought to be 285 bright nebulae within the area of the Milky Way, if the first conclusion holds. This would make one nebula for every 48 square degrees. If we remember that the light of these 12 magnitude objects has to travel across the thickness of the Milky Way, it would seem that only a very minute and systematic search of the photographic

plates can prove the non-existence of bright nebulae beyond the galactic equator.

The objection to the first conclusion is somewhat stronger in the case of dark nebulae, because their apparent extension does not diminish with distance. Probably they have no light of their own and become visible only by the light of the entire stellar system. Now it seems very doubtful whether the light, which they reflect from the extremity of the galactic equator, and which traverses the galaxy, can be perceived by the human eye.

2. The difficulty raised against the second conclusion is, "that the red giants ought to show a connection with dark nebulae," in the sense, that the M giants should be "more numerous *outside* the Milky Way," which is not the case.

In this argument there are two fallacies: First, the distinction between red and white stars is not justified, unless we suppose that the distribution of the dark nebulae is altered while a star grows from the original state to its greatest brilliancy. Second, the stars, red or white, should *not* be more numerous where the clouds are denser. On the contrary, in the densest regions of dark nebulae the star-forming process is supposed to be in abeyance. Absorption of nebulous matter in this process, first by concentration into giant globes and then by contraction into bright stars, is the very basis of the second conclusion.

It is hoped that these explanatory notes will serve to elucidate the state of the question, and to induce those observatories that are free from the illumination of large cities, to apply their visual instruments to the study of the dark cosmic clouds.

Specola Vaticana, Rome,
September 12, 1922.